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State of California  
The Resources Agency  
Department of Water Resources

**FINAL ASSESSMENT OF POTENTIAL  
STURGEON PASSAGE IMPEDIMENTS  
SP-F3.2 TASK 3A**

**Oroville Facilities Relicensing  
FERC Project No. 2100**



SEPTEMBER 2003

**GRAY DAVIS**  
Governor  
State of California

**MARY D. NICHOLS**  
Secretary for Resources  
The Resources Agency

**MICHAEL J. SPEAR**  
Interim Director  
Department of Water  
Resources

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**This report was prepared under the direction of**

Paul Bratovich ..... Principal, SWRI - Fisheries Technical Lead  
David Olson ..... Senior Environmental Scientist, SWRI - Project Manager

**by**

Allison Niggemyer ..... Associate Environmental Scientist, SWRI  
Thomas Duster ..... Associate Environmental Scientist, SWRI

**Assisted by**

Michael Perrone ..... Senior Environmental Scientist, DWR

## TABLE OF CONTENTS

1.0	SUMMARY .....	1-1
2.0	PURPOSE .....	2-1
3.0	BACKGROUND .....	3-1
3.1	Description of Facilities .....	3-1
3.2	Current Operational Constraints .....	3-3
3.2.1	Downstream Operation .....	3-4
3.2.1.1	Instream Flow Requirements .....	3-4
3.2.1.2	Temperature Requirements .....	3-5
3.2.1.3	Water Diversions .....	3-5
3.2.1.4	Water Quality .....	3-6
3.2.2	Flood Management .....	3-6
3.3	Sturgeon Life History .....	3-7
3.4	Physical Performance Parameters for Sturgeon .....	3-7
3.5	General Physical Barrier Characteristics in the Lower Feather River .....	3-8
4.0	METHODOLOGY .....	4-1
5.0	RESULTS .....	5-1
5.1	Shanghai Bench .....	5-1
5.2	Sunset Pumps .....	5-3
5.3	Steep Riffle .....	5-6
5.4	Expert Team Research Suggestions .....	5-6
5.5	General Comments by the Expert Team .....	5-7
5.5-1	Life History and Habitat Requirements .....	5-7
5.5-2	Swimming Speeds .....	5-8
5.5-3	Leaping Ability .....	5-8
5.5-4	Attraction Flow Requirements .....	5-8
6.0	CONCLUSIONS .....	6-1
7.0	REFERENCES .....	7-1

## LIST OF FIGURES

Figure 3.1-1.	Oroville Facilities FERC Project Boundary .....	3-2
Figure 5.1-1.	Aerial photograph of the lower Feather River at Shanghai Bench .....	5-1
Figure 5.1-2.	The lower Feather River downstream of Shanghai Bench where the side channel (river-left) reconnects with the main channel during representative low flow conditions. ....	5-2
Figure 5.1-3.	The lower Feather River at Shanghai Bench during the July 2003 sturgeon passage barrier assessment .....	5-3
Figure 5.2-1.	The lower Feather River at Sunset Pumps during the November 2002 representative low flow sturgeon passage barrier assessment .....	5-4
Figure 5.2-2.	The lower Feather River at Sunset Pumps during the July 2003 representative high flow sturgeon passage barrier assessment. ....	5-5

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Figure 5.3-1. The lower Feather River at the upstream end of Steep Riffle during  
the November 2002 sturgeon passage barrier assessment..... 5-6

## 1.0 SUMMARY

Three potential physical upstream migration barriers for sturgeon in the Feather River were identified and field evaluated during representative low flow (November 2002, approximately 2,074 cfs) and high flow (July 2003, approximately 9,998 cfs) conditions by a team of selected sturgeon passage experts. The three potential physical upstream migration barriers included Shanghai Bench, Sunset Pumps, and Steep Riffle (located two miles upstream of the Thermalito Afterbay Outlet) (USFWS 1995). At the observed representative low flow, Shanghai Bench is likely a sturgeon passage barrier due to the height of its waterfalls, water velocities of the mid-channel chute and lack of attraction flow within the potentially passable side-channel. These potential passage impediments virtually disappear at relatively higher flows, and Shanghai Bench is likely passable for sturgeon during the representative high flow conditions. At the observed representative low flow conditions, Sunset Pumps is likely a sturgeon passage barrier due to the height of its waterfalls and water velocities of the mid-channel chute. The passage of Sunset Pumps by sturgeon during the representative high flow conditions is unlikely, although a potential passage opportunity may exist within a river-left cascade/willow bar complex. Of the potential barriers assessed, Steep Riffle represents the most reasonably passable potential barrier during representative low flow conditions, and sturgeon could likely ascend the riffle without complication. Steep Riffle was removed from evaluation during representative high flow conditions because the expert team deemed that it is likely passable during most river stages. Passage determinations at each of the potential passage barriers in the lower Feather River will continue to be speculative without a greater understanding of sturgeon migration patterns and physiologic limitations.

## 2.0 PURPOSE

Sturgeon are neither commonly nor consistently observed in the Feather River. Because operations of the Oroville Facilities may influence the ability of both green sturgeon and white sturgeon to upmigrate past potential passage impediments by influencing flows within the Feather River, the sturgeon passage assessment portion of SP-F3.2 Task 3A was developed to evaluate the degree to which migration impediments may contribute to the relatively low number and inconsistent observations of sturgeon in the Feather River. This assessment report evaluates the potential for sturgeon passage at three preliminarily identified potential migration barriers during a “variety of flow conditions,” including the “representative low flow range” and “representative high flow range” as directed in SP-F3.2 Task 3A, and represents the final conclusions from the sturgeon passage impediment assessment. In addition to the passage assessment, existing geographic and temporal distribution information for sturgeon also will be augmented by the results of pending radio tracking, scuba and creel surveys conducted during the 2003 field season.

The purpose of this assessment report is to document and communicate the findings of the Feather River sturgeon passage field investigations for the range of flow observations visually evaluated during the representative low and high flow periods. Section 4.51(f)(3) of 18 CFR requires reporting of certain types of information in the Federal Energy Regulatory Commission (FERC) application for license of major hydropower projects, including a discussion of the fish, wildlife, and botanical resources in the vicinity of the project (Code of Federal Regulations 2001). The discussion is required to identify the potential impacts of the project on these resources, including a description of any anticipated continuing impact for on-going and future operations. As a subtask of SP-F3.2, the sturgeon passage assessment fulfills a portion of the FERC application requirements by detailing the potential passage impediments associated with the Oroville project area for green sturgeon, which is a species of special regulatory status, and white sturgeon, which is a species of primary management concern (herein collectively denoted as “sturgeon”). In addition to fulfilling these requirements, information collected during this task may be used in developing or evaluating potential protection, mitigation and enhancement (PM&E) measures.

### **3.0 BACKGROUND**

The study area for this task is defined in SP-F3.2 as the Feather River from the Fish Barrier Dam to the confluence with the Sacramento River (DWR 2002). Shanghai Bench, Sunset Pumps, and Steep Riffle (located upstream of the Thermalito Afterbay Outlet) have been identified as the most likely potential impediments for upstream passage of adult sturgeon (USFWS 1995).

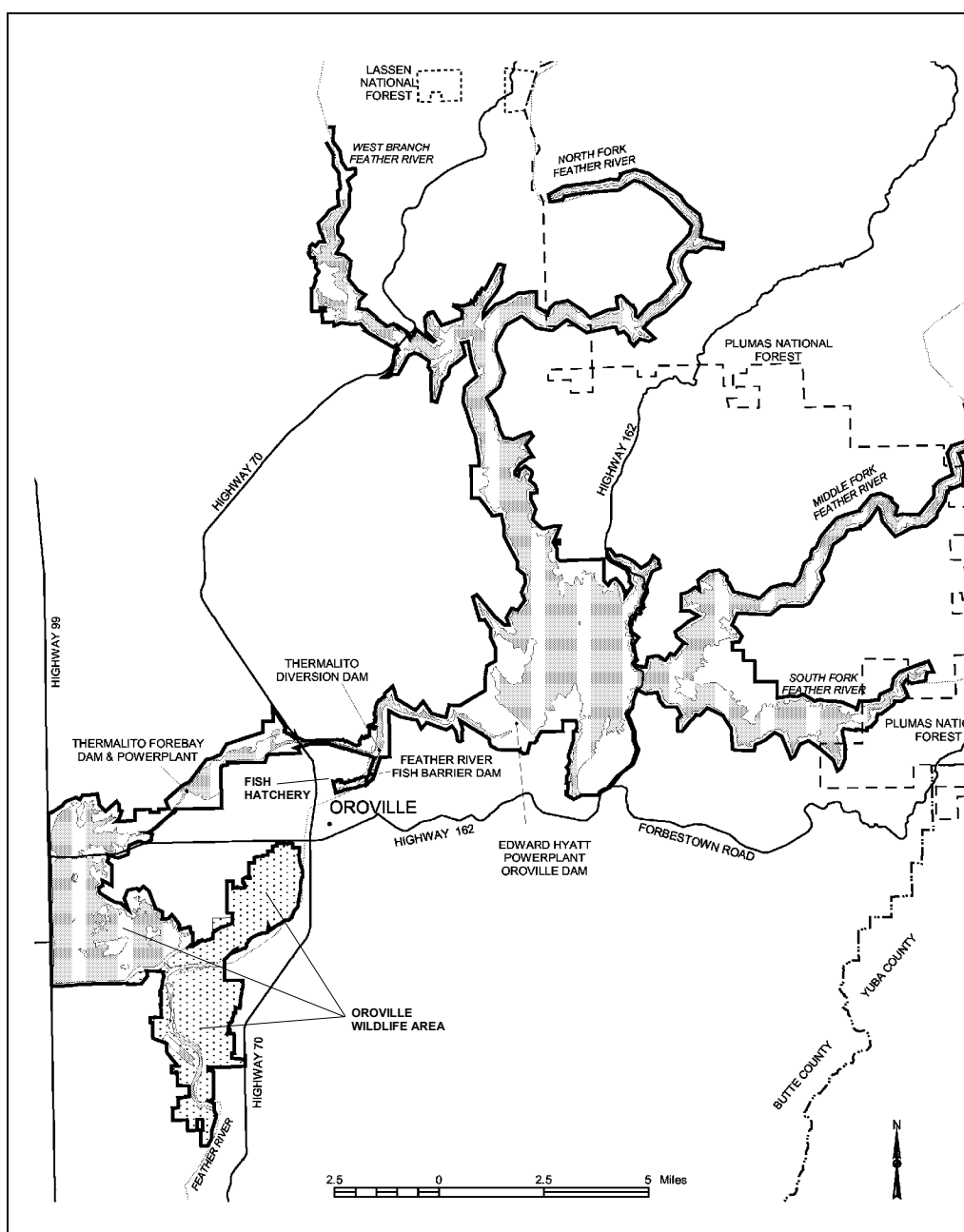
#### **3.1 DESCRIPTION OF FACILITIES**

The Oroville Facilities were developed as part of the State Water Project (SWP), a water storage and delivery system of reservoirs, aqueducts, power plants, and pumping plants. The main purpose of the SWP is to store and distribute water to supplement the needs of urban and agricultural water users in northern California, the San Francisco Bay area, the San Joaquin Valley, and southern California. The Oroville Facilities are also operated for flood management, power generation, to improve water quality in the Delta, provide recreation, and enhance fish and wildlife.

FERC Project No. 2100 encompasses 41,100 acres and includes Oroville Dam and Reservoir, three power plants (Hyatt Pumping-Generating Plant, Thermalito Diversion Dam Power Plant, and Thermalito Pumping-Generating Plant), Thermalito Diversion Dam, the Feather River Fish Hatchery and Fish Barrier Dam, Thermalito Power Canal, Oroville Wildlife Area (OWA), Thermalito Forebay and Forebay Dam, Thermalito Afterbay and Afterbay Dam, and transmission lines, as well as a number of recreational facilities. An overview of these facilities is provided on Figure 3.1-1. The Oroville Dam, along with two small saddle dams, impounds Lake Oroville, a 3.5-million-acre-foot (MAF) capacity storage reservoir with a surface area of 15,810 acres at its normal maximum operating level.

The hydroelectric facilities have a combined licensed generating capacity of approximately 762 megawatts (MW). The Hyatt Pumping-Generating Plant is the largest of the three power plants with a capacity of 645 MW. Water from the six-unit underground power plant (three conventional generating and three pumping-generating units) is discharged through two tunnels into the Feather River just downstream of Oroville Dam. The plant has a generating and pumping flow capacity of 16,950 cfs and 5,610 cfs, respectively. Other generation facilities include the 3-MW Thermalito Diversion Dam Power Plant and the 114-MW Thermalito Pumping-Generating Plant.

Thermalito Diversion Dam, four miles downstream of the Oroville Dam creates a tail water pool for the Hyatt Pumping-Generating Plant and is used to divert water to the Thermalito Power Canal. The Thermalito Diversion Dam Power Plant is a 3-MW power plant located on the left abutment of the Diversion Dam. The power plant releases a maximum of 615 cubic feet per second (cfs) of water into the river.



**Figure 3.1-1. Oroville Facilities FERC Project Boundary**

The Power Canal is a 10,000-foot-long channel designed to convey generating flows of 16,900 cfs to the Thermalito Forebay and pump-back flows to the Hyatt Pumping-Generating Plant. The Thermalito Forebay is an off-stream regulating reservoir for the 114-MW Thermalito Pumping-Generating Plant. The Thermalito Pumping-Generating Plant is designed to operate in tandem with the Hyatt Pumping-Generating Plant and has generating and pump-back flow capacities of 17,400 cfs and 9,120 cfs, respectively. When in generating mode, the Thermalito Pumping-Generating Plant discharges into the Thermalito Afterbay, which is contained by a 42,000-foot-long earth-fill dam. The

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Afterbay is used to release water into the Feather River downstream of the Oroville Facilities, helps regulate the power system, provides storage for pump-back operations, and provides recreational opportunities. Several local irrigation districts receive water from the Afterbay.

The Feather River Fish Barrier Dam is downstream of the Thermalito Diversion Dam and immediately upstream of the Feather River Fish Hatchery. The flow over the dam maintains fish habitat in the low-flow channel of the Feather River between the dam and the Afterbay outlet, and provides attraction flow for the hatchery. The hatchery was intended to compensate for spawning grounds lost to returning salmon and steelhead trout from the construction of Oroville Dam. The hatchery can accommodate 15,000 to 20,000 adult fish annually.

The Oroville Facilities support a wide variety of recreational opportunities. They include: boating (several types), fishing (several types), fully developed and primitive camping (including boat-in and floating sites), picnicking, swimming, horseback riding, hiking, off-road bicycle riding, wildlife watching, hunting, and visitor information sites with cultural and informational displays about the developed facilities and the natural environment. There are major recreation facilities at Loafer Creek, Bidwell Canyon, the Spillway, North and South Thermalito Forebay, and Lime Saddle. Lake Oroville has two full-service marinas, five car-top boat launch ramps, ten floating campsites, and seven dispersed floating toilets. There are also recreation facilities at the Visitor Center and the OWA.

The OWA comprises approximately 11,000-acres west of Oroville that is managed for wildlife habitat and recreational activities. It includes the Thermalito Afterbay and surrounding lands (approximately 6,000 acres) along with 5,000 acres adjoining the Feather River. The 5,000 acre area straddles 12 miles of the Feather River, which includes willow and cottonwood lined ponds, islands, and channels. Recreation areas include dispersed recreation (hunting, fishing, and bird watching), plus recreation at developed sites, including Monument Hill day use area, model airplane grounds, three boat launches on the Afterbay and two on the river, and two primitive camping areas. California Department of Fish and Game's (DFG) habitat enhancement program includes a wood duck nest-box program and dry land farming for nesting cover and improved wildlife forage. Limited gravel extraction also occurs in a number of locations.

### **3.2 CURRENT OPERATIONAL CONSTRAINTS**

Operation of the Oroville Facilities varies seasonally, weekly and hourly, depending on hydrology and the objectives DWR is trying to meet. Typically, releases to the Feather River are managed to conserve water while meeting a variety of water delivery requirements, including flow, temperature, fisheries, recreation, diversion and water quality. Lake Oroville stores winter and spring runoff for release to the Feather River as necessary for project purposes. Meeting the water supply objectives of the SWP has

always been the primary consideration for determining Oroville Facilities operation (within the regulatory constraints specified for flood control, in-stream fisheries, and downstream uses). Power production is scheduled within the boundaries specified by the water operations criteria noted above. Annual operations planning is conducted for multi-year carry over. The current methodology is to retain half of the Lake Oroville storage above a specific level for subsequent years. Currently, that level has been established at 1,000,000 acre-feet (af); however, this does not limit draw down of the reservoir below that level. If hydrology is drier than expected or requirements greater than expected, additional water would be released from Lake Oroville. The operations plan is updated regularly to reflect changes in hydrology and downstream operations. Typically, Lake Oroville is filled to its maximum annual level of up to 900 feet above mean sea level (msl) in June and then can be lowered as necessary to meet downstream requirements, to its minimum level in December or January. During drier years, the lake may be drawn down more and may not fill to the desired levels the following spring. Project operations are directly constrained by downstream operational constraints and flood management criteria as described below.

### **3.2.1 Downstream Operation**

An August 1983 agreement between DWR and DFG entitled, "Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish & Wildlife," sets criteria and objectives for flow and temperatures in the low flow channel and the reach of the Feather River between Thermalito Afterbay and Verona. This agreement: (1) establishes minimum flows between Thermalito Afterbay Outlet and Verona which vary by water year type; (2) requires flow changes under 2,500 cfs to be reduced by no more than 200 cfs during any 24-hour period, except for flood management, failures, etc.; (3) requires flow stability during the peak of the fall-run Chinook spawning season; and (4) sets an objective of suitable temperature conditions during the fall months for salmon and during the later spring/summer for shad and striped bass.

#### ***3.2.1.1 Instream Flow Requirements***

The Oroville Facilities are operated to meet minimum flows in the Lower Feather River as established by the 1983 agreement (see above). The agreement specifies that Oroville Facilities release a minimum of 600 cfs into the Feather River from the Thermalito Diversion Dam for fisheries purposes. This is the total volume of flows from the diversion dam outlet, diversion dam power plant, and the Feather River Fish Hatchery pipeline.

Generally, the instream flow requirements below Thermalito Afterbay are 1,700 cfs from October through March, and 1,000 cfs from April through September. However, if runoff for the previous April through July period is less than 1,942,000 af (i.e., the 1911-1960 mean unimpaired runoff near Oroville), the minimum flow can be reduced to 1,200 cfs

from October to February, and 1,000 cfs for March. A maximum flow of 2,500 cfs is maintained from October 15 through November 30 to prevent spawning in overbank areas that might become de-watered.

### **3.2.1.2 Temperature Requirements**

The Diversion Pool provides the water supply for the Feather River Fish Hatchery. The hatchery objectives are 52°F for September, 51°F for October and November, 55°F for December through March, 51°F for April through May 15, 55°F for last half of May, 56°F for June 1-15, 60°F for June 16 through August 15, and 58°F for August 16-31. A temperature range of plus or minus 4°F is allowed for objectives, April through November.

There are several temperature objectives for the Feather River downstream of the Afterbay Outlet. During the fall months, after September 15, the temperatures must be suitable for fall-run Chinook. From May through August, they must be suitable for shad, striped bass, and other warmwater fish.

The National Marine Fisheries Service has also established an explicit criterion for steelhead trout and spring-run Chinook salmon. Memorialized in a biological opinion on the effects of the Central Valley Project and SWP on Central Valley spring-run Chinook and steelhead as a reasonable and prudent measure; DWR is required to control water temperature at Feather River mile 61.6 (Robinson's Riffle in the low-flow channel) from June 1 through September 30. This measure requires water temperatures less than or equal to 65°F on a daily average. The requirement is not intended to preclude pump-back operations at the Oroville Facilities needed to assist the State of California with supplying energy during periods when the California ISO anticipates a Stage 2 or higher alert.

The hatchery and river water temperature objectives sometimes conflict with temperatures desired by agricultural diverters. Under existing agreements, DWR provides water for the Feather River Service Area (FRSA) contractors. The contractors claim a need for warmer water during spring and summer for rice germination and growth (i.e., 65°F from approximately April through mid May, and 59°F during the remainder of the growing season). There is no obligation for DWR to meet the rice water temperature goals. However, to the extent practical, DWR does use its operational flexibility to accommodate the FRSA contractor's temperature goals.

### **3.2.1.3 Water Diversions**

Monthly irrigation diversions of up to 190,000 (July 2002) af are made from the Thermalito Complex during the May through August irrigation season. Total annual entitlement of the Butte and Sutter County agricultural users is approximately 1 MAF. After meeting these local demands, flows into the lower Feather River continue into the

Sacramento River and into the Sacramento-San Joaquin Delta. In the northwestern portion of the Delta, water is pumped into the North Bay Aqueduct. In the south Delta, water is diverted into Clifton Court Forebay where the water is stored until it is pumped into the California Aqueduct.

#### **3.2.1.4 Water Quality**

Flows through the Delta are maintained to meet Bay-Delta water quality standards arising from DWR's water rights permits. These standards are designed to meet several water quality objectives such as salinity, Delta outflow, river flows, and export limits. The purpose of these objectives is to attain the highest water quality, which is reasonable, considering all demands being made on the Bay-Delta waters. In particular, they protect a wide range of fish and wildlife including Chinook salmon, Delta smelt, striped bass, and the habitat of estuarine-dependent species.

#### **3.2.2 Flood Management**

The Oroville Facilities are an integral component of the flood management system for the Sacramento Valley. During the wintertime, the Oroville Facilities are operated under flood control requirements specified by the U.S. Army Corps of Engineers (USACE). Under these requirements, Lake Oroville is operated to maintain up to 750,000 af of storage space to allow for the capture of significant inflows. Flood control releases are based on the release schedule in the flood control diagram or the emergency spillway release diagram prepared by the USACE, whichever requires the greater release. Decisions regarding such releases are made in consultation with the USACE.

The flood control requirements are designed for multiple use of reservoir space. During times when flood management space is not required to accomplish flood management objectives, the reservoir space can be used for storing water. From October through March, the maximum allowable storage limit (point at which specific flood release would have to be made) varies from about 2.8 to 3.2 MAF to ensure adequate space in Lake Oroville to handle flood flows. The actual encroachment demarcation is based on a wetness index, computed from accumulated basin precipitation. This allows higher levels in the reservoir when the prevailing hydrology is dry while maintaining adequate flood protection. When the wetness index is high in the basin (i.e., wetness in the watershed above Lake Oroville), the flood management space required is at its greatest amount to provide the necessary flood protection. From April through June, the maximum allowable storage limit is increased as the flooding potential decreases, which allows capture of the higher spring flows for use later in the year. During September, the maximum allowable storage decreases again to prepare for the next flood season. During flood events, actual storage may encroach into the flood reservation zone to prevent or minimize downstream flooding along the Feather River.

### **3.3 STURGEON LIFE HISTORY**

Sturgeon are anadromous fish that spawn in rivers, but spend most of their life in estuarine and marine environments. On the west coast of North America, sturgeon can range geographically from southern Alaska to Mexico (Beamesderfer et al. 2002). Sturgeon are known to migrate into the Feather River, but detailed information regarding their reproduction is limited (USFWS 1995). During the mid-1970s, green sturgeon reportedly were captured each year in the Feather River, with the majority of catches occurring between March and May, and a few additional catches occurring during July and August (USFWS 1995). As recently as 1993, adult green sturgeon have been caught near the Thermalito Afterbay Outlet (USFWS 1995).

Adult green sturgeon appear to begin migration upstream into freshwater during the latter part of February and, in the Sacramento River, may continue migrating up to 200 miles upstream before spawning (Beamesderfer et al. 2002). Adult white sturgeon begin migrating into the Sacramento River during October (USFWS 1995). Although most white sturgeon spawning occurs during March and April, spawning may begin as early as February and may continue into June (USFWS 1995). Catch data indicate that most green and white sturgeon spawning in the Feather River occurs between March and May (USFWS 1995).

In areas outside of the Central Valley, sturgeon spawn over rocks, compact clay substrates, or large gravels at depths up to approximately 30 feet (9.1 meters) with water velocities ranging from 5 to 10 feet/second (1.5 to 3.0 meters/second). Spawning sturgeon in the Central Valley have been observed using gravel, rubble or soft-bottomed stream reaches (USFWS 1995). On the Rogue River in Oregon, holding sites are typically deeper than 16.4 feet (5 meters), with in-river residence times of up to 6 months (Grimaldo et al. 2001). Spawning locations for sturgeon in the Feather River are unknown, but it has been suggested that spawning may be limited to areas immediately downstream of the Thermalito Afterbay Outlet (USFWS 1995). Similarly, it also has been suggested that angler catch rates indicate that spawning may occur downstream of the Thermalito Afterbay Outlet and Gridley Bridge (USFWS 1995).

### **3.4 PHYSICAL PERFORMANCE PARAMETERS FOR STURGEON**

Typical passage assessment methodologies rely upon the relationship between physical metrics of fish swimming performance (i.e., burst speed, sustained speed, and leaping ability curves) and the physical characteristics of the barrier being assessed. Unfortunately, relative to salmonids, limited information exists regarding sturgeon swimming or leaping performance. In fact, a review of the available literature did not provide metrics suitable for quantifying sturgeon swimming performance.

Due to the paucity of available swimming performance data, and the anticipated challenges of field data collection, information on both the green and white sturgeon is

being collected in laboratory settings in an effort to gain a better understanding of sturgeon passage abilities. For example, Dr. Joseph Cech (University of California at Davis [UCD]) is performing several experiments on sturgeon in a swimming flume to quantify sturgeon swimming performance. To date, only preliminary results of these experiments exist, but it is expected that these tests may eventually provide useful information related to sturgeon burst and sustained swimming speeds, velocity refuge utilization, and substrate preferences for use in future passage assessments.

Because detailed passage criteria, such as those developed for salmonids, have not been developed for green or white sturgeon, several methods were proposed in combination to evaluate sturgeon passage at the identified potential upstream migration barriers in the lower Feather River. The passage evaluation methods utilized were necessarily either subjective or exploratory due to the lack of quantitative passage information. The evaluation methods being conducted as part of the Oroville Facilities Relicensing include exploratory scuba diving surveys, creel surveys, sturgeon radio tracking surveys, and visual assessments of the potential passage barriers by a team of sturgeon passage experts. The final passage assessment results elucidated in this document will primarily communicate the visual evaluation of potential passage barriers, because the other indicated evaluation methods are presently underway.

### **3.5 GENERAL PHYSICAL BARRIER CHARACTERISTICS IN THE LOWER FEATHER RIVER**

In the lower Feather River, three potential physical upstream migration barriers have been identified for sturgeon including: (1) Shanghai Bench; (2) Sunset Pumps; and (3) Steep Riffle located in the reach 1 to 2 miles upstream of the Thermalito Afterbay Outlet (USFWS 1995). During relatively low flow conditions, three distinct barrier types characterize Shanghai Bench. Waterfalls emerge throughout most of the main river channel, and a high velocity chute and shallow side channel exist river-left. The potential migration barrier at Sunset Pumps consists of a rock dam, which spans the entire river channel, with the exception of one “notch” that forms a high velocity chute through the dam. The notch formerly existed near the middle of the structure, but recent dam modifications now situate it in a river-right location. Steep Riffle consists of a shallow, intermediate-velocity, high gradient riffle, which past migration surveys have suggested may inhibit sturgeon passage during particular flow conditions (USFWS 1995). Specific physical characteristics of each potential upstream migration barrier during a particular observed flow are detailed and illustrated in Section 5.0 Results.

## 4.0 METHODOLOGY

The three potential sturgeon upstream migration barriers were evaluated by a team of selected sturgeon passage experts during representative low and high flow conditions on November 9, 2002 and July 15, 2003, respectively. The November 2002 expert team consisted of the following representatives from various agencies and academia:

- Dr. Joseph Cech, UCD
- Scott Lankford, UCD
- Jason Webber, UCD
- Eric Theiss, National Oceanic and Atmospheric Administration (NOAA) Fisheries
- Michael Perrone, California Division of Water Resources (DWR)
- Dave Gonzalez, California DWR
- David Olson, Surface Water Resources, Inc. (SWRI)
- Thomas Duster, SWRI

Due to scheduling conflicts, several members of the November 2002 team were unavailable to provide technical assistance during the July 2003 assessment, while several new experts were added. As such, the July 2003 expert team consisted of the following representatives:

- Eric Theiss, NOAA Fisheries
- Rich DeHaven, U.S. Fish and Wildlife Service (USFWS)
- Alicia Seesholtz, California DWR
- Dave Gonzalez, California DWR
- David Olson, SWRI
- Adrian Pitts, SWRI.
- Thomas Duster, SWRI

The sturgeon passage experts traveled to each potential upstream migration barrier during the November 2002 assessment; however, due to the general agreement that Steep Riffle would likely be passable to migrating sturgeon during most flow conditions, it was excluded from the July 2003 assessment. Daily average flows in the Feather River near Gridley (CDEC Station ID: GRL) were approximately 2,074 cubic feet per second (cfs) and 9,998 cfs during the November 2002 and July 2003 assessments, respectively (<http://cdec.water.ca.gov>).

During each potential barrier evaluation, the passage experts specifically assessed the likelihood of passage at each impediment during the observed flow conditions. The expert team noted the physical characteristics of each passage evaluation site, and captured the sites on video and in photographs. The opinions, rationale for conclusions, and site-specific factors for consideration described by each passage expert team member also were documented. Due to the lack of quantified parameters regarding the

physiologic capabilities of sturgeon, the expert team mainly relied upon their best professional judgment when considering the likelihood of passage at each barrier. To the extent possible, the team also attempted to characterize the substrate at the potential passage barriers and estimate whether the substrate was suitable to allow sturgeon to “walk” or “scootch” up the potential barrier during the observed flows. However, because sturgeon substrate preferences related to these modes of locomotion are limited, a detailed substrate characterization was not conducted. Safety considerations also inhibited the collection of quantitative physical impediment metrics and substrate data at each assessment site.

In addition to the passage assessment at each potential barrier, the expert team offered numerous ideas regarding experimental design options to further evaluate the migration ability and behavior of sturgeon in the lower Feather River. These ideas were documented, and will be utilized in the design of future sturgeon investigations, including the sturgeon radio tracking studies.

## 5.0 RESULTS

### 5.1 SHANGHAI BENCH

During the November 2002 low flow evaluation at Shanghai Bench, the passage expert team observed and evaluated three distinct potential migration barrier-types, including a set of waterfalls, a high-velocity chute, and a side channel (**Figure 5.1-1**). The waterfalls at Shanghai Bench measure approximately 3 to 5 feet (0.9 to 1.5 meters) in vertical height and stretched across much of the main river channel. A chute existing river-left of the main channel exhibited relatively high velocities, estimated at greater than 3.3 feet/second (1 meter/second). River-left of the waterfalls and chute, a side channel with much lower velocities relative to the main channel was characterized. The depth of the side channel ranged from approximately 0.5 to 3 feet, and the channel captured only a very small proportion (e.g., 10%) of the total flow.

The passage expert team concluded that sturgeon do not likely have the leaping ability to jump over the waterfalls existing at Shanghai Bench during the November 2002 assessment. Therefore, the falls at Shanghai Bench likely represent a vertical height migration barrier during the representative low flow. It was also concluded that sturgeon do not likely have the swimming ability to swim or “scotch” up the high-velocity chute. However, some members of the team postulated that there may be small pockets of passable water velocities created by rough substrate within or along the margins of the chute. In addition, it is unknown whether a green sturgeon would choose to enter an area of such volatile and dynamic flow, even if areas of appropriate velocities are present within or near the Shanghai Bench chute.



**Figure 5.1-1. Aerial photograph of the lower Feather River at Shanghai Bench (taken June 2002).**

Finally, because information regarding the mechanisms of attraction for sturgeon is limited, the passage team could not conclude whether the side channel existing during the November 2002 low flow assessment carried a sufficient quantity or relative proportion of the total river flow to attract migrating sturgeon. If attracted, the extent to which sturgeon could navigate the shallow portions of the side channel is unknown and could constitute another migration barrier consideration (**Figure 5.1-2**).



**Figure 5.1-2.** The lower Feather River downstream of Shanghai Bench where the side channel (river-left) reconnects with the main channel during representative low flow conditions.

In general, the expert team concluded that Shanghai Bench is likely a passage barrier to immigrating adult sturgeon during flows approximated by the November 2002 representative low flow conditions. However, the expert team agreed that further information regarding sturgeon swimming performance, utilization of shallow channels, substrate for “perching” or “scootching,” as well as migration attraction flow requirements, would be needed to definitively determine the likelihood of passage at Shanghai Bench during relatively low flow conditions.

Shanghai Bench exhibited vastly different characteristics during the July 2003 sturgeon passage assessment relative to the November 2002 evaluation (**Figure 5.1-3**). The relatively high representative flow conditions had inundated virtually all physical channel features observed during lower flows, creating a river reach nearly devoid of obvious potential physical migration barriers. The expert team agreed that immigrating sturgeon would likely be capable of finding an acceptable path through the physical features which remained. The greater volume of water passing the site appeared to distribute throughout the channel, thereby holding water velocities at Shanghai Bench within a range deemed acceptable by the expert team for sturgeon passage. The expert team

generally agreed that the potential migration barrier existing at Shanghai Bench is likely passable, particularly by large adult sturgeon, during flows approximated by the July 2003 representative high flow conditions.



**Figure 5.1-3.**The lower Feather River at Shanghai Bench during the July 2003 sturgeon passage barrier assessment.

## **5.2 SUNSET PUMPS**

The potential sturgeon migration barrier located at Sunset Pumps consists of a rock dam, which spans the entire river channel. During the November 2002 sturgeon passage assessment, a backwater eddy was created river-left downstream of the rock dam. During these representative low flow conditions, the expert team observed and evaluated two potential migration barrier-types including a high velocity chute and the waterfalls which frame it (**Figure 5.2-1**). A relatively high velocity chute, estimated to have surface water velocities of over 3.3 feet/second (1 meters/sec), existed in a notch in the rock dam near the middle of its span. Water also passed over many areas of the dam, creating waterfalls of approximately 3 to 4 feet (0.9 to 1.2 meters) in vertical height.



**Figure 5.2-1.** The lower Feather River at Sunset Pumps during the November 2002 representative low flow sturgeon passage barrier assessment.

While there was interest in gathering information regarding the substrate roughness and water column velocities of the chute, the preliminary assessment of the November 2002 representative low flow conditions concluded in a consensus that sturgeon do not likely have the swimming ability to swim or “scootch” up the chute. However, some members of the team postulated that small pockets of passable velocities created by rough substrate may exist within or along the margins of the chute. In addition, the expert team concluded that at the observed representative low flow levels, sturgeon do not likely have the leaping ability to jump over the waterfalls which cascaded over the rock dam at Sunset Pumps. It is therefore likely that the waterfalls represent a vertical height migration barrier.

In general, the expert team concluded that the Sunset Pumps location is likely a passage barrier at the evaluated November 2002 representative low flow conditions. However, further investigation regarding the substrate of the river channel and the micro-velocities existing adjacent to the high-velocity chute, as well as definitive information related to sturgeon swimming performance and velocity refuge utilization, would be needed to definitively determine the likelihood of passage at Sunset Pumps.

During the July 2003 representative high flow passage assessment, Sunset Pumps appeared markedly similar to the representative low flow observations, with the exception of a mechanical alteration to the rock dam. Between the dates of the November 2002 and July 2003 assessments, construction at Sunset Pumps had moved the notch in the dam from the middle of the dam span to the extreme river-right bank (**Figure 5.2-2**). The magnitude and characteristics of other dam modifications during

construction activities unknown, making for a difficult comparison of dam characteristics between assessment dates. However, water velocities in the resituated chute, estimated at 10 to 15 feet/second (3 to 4.5 meters/second), far exceeded the reasonable sturgeon passage criteria estimated by the expert passage team. In addition, the expert team determined that it was unlikely pockets of sufficiently low water velocities existed beneath the turbulent chute to facilitate sturgeon passage by swimming or scootching. The rock dam which constituted the remainder of the potential passage barrier was not inundated at the representative high flow, although several waterfalls did exist on the edges of the dam, similar in characteristics to those existing under the relatively low flow conditions. Again, the passage expert team concluded that the waterfalls and rock dam were of sufficient height to inhibit migration by an immigrating adult sturgeon. However, a subset of members of the passage assessment team (E. Theiss [NOAA Fisheries], and R. DeHaven [USFWS]), while subsequently evaluating the Sunset Pumps barrier from a viewpoint across the river, did find an area of potentially suitable characteristics for adult sturgeon to navigate the barrier. This potential passage zone consisted of a small cascade between a grouping of shrubby bars on a river-left location.



**Figure 5.2-2. The lower Feather River at Sunset Pumps during the July 2003 representative high flow sturgeon passage barrier assessment.**

### 5.3 STEEP RIFFLE

The passage team evaluated Steep Riffle only during the November 2002 representative low flow assessment for potential migration barrier-types. Steep Riffle is a relatively high gradient riffle with intermediate water velocities, estimated at approximately 1 to 2 feet/second (0.3 to 0.6 meters/second) and water depths, in places, of less than 1 foot (0.3 meters), especially in the upstream reach. The passage team concluded that Steep Riffle represented the most reasonably passable potential barrier for sturgeon. While the relatively shallow depths of the channel create potential passage concerns and do merit further evaluation, it was determined that sturgeon should be able to ascend the riffle without complication. The riffle was observed at a flow of 600 cfs, which is a representative and typical flow for the low-flow channel upstream of the Thermalito Afterbay Outlet (**Figure 5.3-1**). Therefore, the expert team concluded that Steep Riffle would not be included in further passage investigations, including the July 2003 representative high flow observations.



**Figure 5.3-1.**The lower Feather River at the upstream end of Steep Riffle during the November 2002 sturgeon passage barrier assessment.

### 5.4 EXPERT TEAM RESEARCH SUGGESTIONS

The sturgeon passage experts generally believe that passage determinations at each of the potential passage barriers will continue to be speculative without a greater understanding of sturgeon migration patterns, and physiologic capabilities. Upon consideration of the abiotic and biotic characteristics of each potential passage barrier, the expert team provided a number of research suggestions which, in conjunction with a greater understanding of the geomorphologic characteristics of each site (i.e., exact

waterfall heights, substrate descriptions, water velocity profiles, etc.), would be useful in determining the migratory ability and behavior of sturgeon in the lower Feather River.

Tracking studies would greatly enhance the ability to understand movement patterns and habitat preferences of sturgeon throughout the Feather River. The studies could utilize sturgeon caught by anglers, or UCD may be able to provide wild-caught fish for release after their laboratory studies, upon regulatory agency approval. The tracking studies could identify passage barriers in the Feather River by pinpointing the locations of significant delay and upstream migratory extent of the tagged migrating fish (when considered in conjunction with abiotic and biotic factors). It is also possible to develop a tracking methodology that could identify the exact migration route. For instance, because the representative low flow conditions at Shanghai Bench create a side channel which merits evaluation of its suitability to attract a migrating sturgeon, sufficiently-sensitive tracking stations could be appropriately positioned to determine whether the sturgeon utilize the secondary channel migration route. This information, combined with other tracking conclusions, would contribute considerable knowledge to the understanding of sturgeon in the Feather River and elsewhere.

The variables that represent the most important factors when considering sturgeon passage are height of falls, depth of water, water velocity, and substrate. UCD has commenced laboratory experimentation to determine the extent to which each of these factors affect sturgeon migration. Each pertinent variable will be controlled in laboratory flumes to assess sturgeon swimming ability, substrate preferences, and other performance and preference characteristics. The result of the laboratory studies can then be applied to future field passage assessments. It is important to note that laboratory results regarding many aspects of sturgeon migration may not apply directly to wild fish, because the tests will be conducted in straight flumes rather than in the complex habitat and hydraulic diversity of a large river. The laboratory results will then need to be validated with field programs.

## **5.5 GENERAL COMMENTS BY THE EXPERT TEAM**

During the passage barrier assessment, the following comments were captured regarding sturgeon life history and migration characteristics:

### **5.5-1 Life History and Habitat Requirements**

- Sturgeon likely hold in deep holes.
- Sturgeon likely spawn in high-velocity, turbid riffles.
- Proper sturgeon spawning substrate likely consists of large boulders, cobbles, or possibly even riprap.
- Sturgeon would likely be present in the Feather River in January, February, and March.

### **5.5-2 Swimming Speeds**

- Definitions
  - Sustained cruising speed is continued indefinitely if given unlimited energy.
  - Burst speeds can be continued for approximately 5-6 minutes.
- Laboratory-raised green sturgeon exhibit sustained cruising speeds of approximately 0.75 body lengths/second. Interpolating these results for wild-raised and reared sturgeon, the sustained cruising speed would likely approximate one body length/second. Burst speeds are undoubtedly greater, but are currently unknown.

### **5.5-3 Leaping Ability**

- Sturgeon have relatively poor leaping ability. For instance, at fish ladders in the Pacific Northwest, tens of thousands of salmon and thousands of lampreys pass the fish ladders annually, while only 5 to 10 sturgeons are able to pass due to their leaping limitation.

### **5.5-4 Attraction Flow Requirements**

- Very little is known about sturgeon attraction flow and channel selection requirements. However, the following are anecdotal observations:
  - Sturgeon ascend the Yolo Bypass on the Sacramento River, where a relatively small proportion of main channel flow exists.
  - At Ishi Pishi Falls on the Klamath River, sturgeon have been observed attempting to ascend many possible passage routes until finding an appropriate path.
  - Local fishing guides report that a flow of 5,000 cfs (142 m<sup>3</sup>/sec) at Verona attracts sturgeon into the Feather River.

## 6.0 CONCLUSIONS

The following conclusions resulted from the implementation and analysis of the sturgeon upstream migration passage barrier assessment for the lower Feather River.

1. Passage determinations at each of the potential passage barriers in the lower Feather River will continue to be speculative without a greater understanding of sturgeon migration patterns, and physiologic capabilities.
2. During the representative low flow conditions, Shanghai Bench is likely a sturgeon passage barrier due to the height of its waterfalls, water velocities of the mid-channel chute, and lack of attraction flow to the potentially passable side-channel.
3. During the representative high flow conditions, Shanghai Bench is essentially devoid of significant migration barriers and, as such, is likely passable for immigrating adult sturgeon.
4. During the representative low flow conditions, Sunset Pumps is likely a sturgeon passage barrier due to the height of its waterfalls, and water velocities of the mid-channel chute.
5. During the representative high flow conditions, the likelihood of passage at Sunset Pumps is unknown. While the barrier likely represents a sturgeon passage barrier due to the height of its waterfalls and water velocities of the river-right chute (created by a mechanical alteration since the low flow assessment), a potential passage route may exist within a river-left cascade/willow bar complex.
6. Of the potential barriers assessed, Steep Riffle represents the most reasonably passable potential barrier, and sturgeon could likely ascend the riffle without complication.
7. The extent to which the aforementioned potential sturgeon passage impediments limited the abundance of green or white sturgeon in the Feather River is largely unknown. A conclusion regarding this matter would require analysis of several factors including, but not necessarily limited to: (1) sturgeon life history patterns; (2) Feather River hydrologic characteristics (3) the relationship between actual instream flows and a definitive passage potential at each of the identified potential passage barriers; (4) sturgeon abundance trends throughout the Central Valley; and (5) out-of-basin factors which may limit sturgeon abundance.
8. Tracking studies would greatly enhance the ability to understand migration routes, seasonal movement patterns and habitat preferences of sturgeon throughout the Feather River.

9. The variables that represent the most important factors when considering sturgeon passage are likely height of falls, depth of water, water velocity, and substrate, all of which are currently being evaluated in a UCD laboratory investigations.

## 7.0 REFERENCES

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